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Guidance for Air Quality Monitoring Network Design and Instrument Siting Supplement A. CO Siting

(U.S.) Environmental Protection Agency
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The purpose of this supplement is to provide further assistance in resolving questions which commonly arise in the siting of CO monitors. The main body of the guideline document (OAQPS #1.2-012) contains summaries of the information provided in detail in this attachment. This supplement represents the most current OAQPS position on the siting of CO instruments and supercedes all previous guidance material previously issued.

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GUIDELINE SERIES

OAQPS NO. 1.2-012 R1
(Revised 6/75)

GUIDANCE FOR AIR QUALITY MONITORING
NETWORK DESIGN AND INSTRUMENT SITING

SUPPLEMENT A

CO SITING

U.S. ENVIRONMENTAL PROTECTION AGENCY

Office of Air Quality Planning and Standards

Research Triangle Park, North Carolina

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CO SITING

OAQPS #1.2-012
(REVISED 9/75)

SUPPLEMENT A

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I. INTRODUCTION

The purpose of this supplement is to provide further assistance in resolving questions which commonly arise in the siting of CO monitors. The main body of the guideline document (OAQPS #1.2-012) contains summaries of the information provided in detail in this attachment. This supplement represents the most current OAQPS position on the siting of CO instruments and supercedes all previous guidance material previously issued.

The most important point in this guidance is that the location of all monitoring sites should be standardized to the maximum extent possible. This is essential in order to interpret data between and within cities in a meaningful way and to develop effective and equitable control plans. For CO, this standardization is even more important due to the nature of the pollutant, i.e., its sources, sinks, concentration gradients near roadways and the relative proximity of sources and receptors. It is important to note, however, that existing CO monitors not adhering strictly to the location criteria described herein may still be suitable for various purposes such as the evaluation of ambient air quality with respect to standards. Only through case-by-case evaluation of the siting criteria can definitive statements be made about a monitor's suitability.

II. MONITORING OBJECTIVES

The first step in monitoring network design is to determine the objectives of the monitoring program as a whole, and to identify specific monitoring objectives on a site by site basis. The general location of the monitoring instrument to fulfill these objectives may then be determined. The monitoring objectives for which CO siting criteria will be developed in this guideline are:

1. Evaluate attainment and maintenance of standards.
2. Determination of trends.
3. Evaluation of control tactics.
4. Review of new sources

There are, however, many other important monitoring objectives. Sites which fulfill other monitoring objectives usually require such highly specific and unique site criteria that they are beyond the scope of this guideline and must be developed on a case-by-case basis. Examples are: research into the magnitude of sources and sinks, developing a data base for environmental impact statements, developing a data base for health effects research and developing, evaluating and refining air pollution dispersion models.

A. Attainment And Maintenance Of Standards

It can be inferred from the air quality standards that the most important locations for air quality measurements are those that combine the highest concentrations with the greatest exposures of population. Among the more likely locations for such a combination is the downtown street canyon which has high traffic densities, confined spaces between buildings, and large numbers of people present. In the neighborhoods, concentrations may be less, but people spend greater periods of time exposed to them. Thus, likely types of sites are, street canyon, neighborhood and corridor. These types of sites must of necessity be fixed and long-term (on the order of 2 to 3 years). In areas where scheduled events are expected to produce high traffic densities, mobile monitors could be used. Examples of these types of activities are sporting events, entertainment extravaganzas or an occasional state fair or circus extending over many days.

B. Determination Of Trends

Neighborhood and to a lesser extent, corridor sites are of the most use in determining trends occurring over a wide area. Street canyon sites often are exposed to erratic fluctuations in emissions over relatively small areas but may be valuable in determining trends in maximum values or number and/or percent of time above the standards. As

implied by the term trend monitoring, these types of sites must remain fixed for long periods of time (4 years or longer).

C. Evaluate Results Of Control Measures

There are many possible control measures that could be evaluated. Some are essentially region-wide, such as transportation system changes or exhaust emission controls. For these, sites characterizing neighborhood concentrations are suitable because they will measure the results of the controls without being unduly influenced by large, unrelated fluctuations in local emissions. For specific, smaller scale control measures, monitors that will characterize street canyons or corridors affected by the control measure will be more appropriate. The evaluation of some control measures on this scale may only require monitoring for a limited period of time, perhaps a week or two in different seasons. Among such control measures are traffic engineering changes that would improve traffic flow in a limited part of the downtown area. Further, the types of sites used in the development of control measures could certainly be used in the evaluation of the effectiveness of such measures.

D. Review of New Sources

For CO, a new source review would usually pertain to a facility, building, structure or installation which attracts or may attract mobile source activity that results in emissions which could threaten the ambient CO standard(s). However, on occasion, a new industrial source that emits large quantities of CO will have to undergo review. For such review, it is frequently necessary to obtain a baseline estimate of 1- and 8-hour CO concentrations at the site of a proposed source. Such estimates may then be used either in the CO screening technique[1] or in modeling approaches[1] used to estimate whether a proposed source may pose a threat to the National Air Quality Standards (NAAQS) for CO. Generally, the most suitable type

of station at which to obtain CO data for the review of a new source would be one which is located at the site of the proposed source and is likely to provide a good estimate of urban background concentrations which are independent of the sources operation. A monitoring site used to obtain ambient CO data for new source review is likely to be a short term rather than a permanent one, on the order of several weeks to several months.

It may sometimes be of interest to locate a monitoring station near major arterial streets servicing a new source. Such sites are most likely to be ones which will be used to determine the attainment and maintenance of standards or to determine trends. In addition, such sites may sometimes be used to provide data to validate modeling approaches.

III. GENERAL NUMBER AND TYPES OF SITES NEEDED TO DESCRIBE REGIONAL CO LEVELS

The number of CO monitors prescribed in the minimum network requirements in the Federal Register[2] may or may not be entirely adequate to describe CO levels in an AQCR. Total numbers of sites should be based on the need for data but should not, in general, be fewer than the minimum requirements. The intent of this guideline is not to necessarily advocate more monitoring sites but to stress quality of siting and operation of existing sites. For instance, it is better to have 3 or 4 monitors, well sited and producing valid data than 10 monitors located and operated in a haphazard manner. To this end, we are advocating standardized site exposure criteria.

Practically, the number of monitors available to an agency is dictated primarily by its resources. The number of monitors and personnel available to operate them will influence the location of these monitors. A real problem that may arise is that, if there is a lack of personnel to operate, maintain and calibrate these monitors at optimum locations, some monitors may not be located to fulfill the monitoring objectives intended.

Since AQCR's are so diverse in their makeup (population, emission sources and densities, topography, climatology, land use and transportation habits, etc.), no absolute number of CO sites can be prescribed which is generally applicable for all AQCR's based upon some regional characteristic. Nor can some uniform distribution of site types be prescribed that would be appropriate for all regions. However, we have detailed below some general types of sites and proposed relative priorities which should be considered in conjunction with a particular region's ultimate monitoring objectives. These priorities are not universally applicable to all regions and certainly we are not recommending that if a region has 6 CO monitors, one should be sited in each category. On the contrary, we recommend the bulk of the CO monitoring be confined to priority 1 and 2 type sites. Sites of lower priority, i.e., 3, 4 and 5 are presented only to further standardize siting criteria for those regions who, upon analyses of their own monitoring objectives, have determined a need to monitor in these areas. Table 1 summarizes those suggested priorities.

The types of CO sites which meet the objectives of the monitoring program discussed previously are elaborated below. It is recommended that these types of sites be used whenever possible to encourage standardization.

A. Street Canyon

This site type is usually within the central business district (CBD) in an area of congested stop and go traffic, with relatively uniform and tall buildings (five stories or higher) lining both sides of the street. This type of site can be further divided into two types, i.e., peak and average.

1. Peak

Monitoring at this type of site is the highest priority within the AQCR. By 'peak,' we do not mean the actual point of maximum concentration, even though monitoring

TABLE 1
Suggested Priorities of CO Monitoring Sites

Site Types	Priority
Peak Street Canyon	#1
Peak Neighborhood	#1
Average Street Canyon	#2
Corridor	#3
Background	#4
Average Neighborhood	#5

regulation (40 CFR 51.17) specify at least one site (per pollutant) be located to measure maximum concentrations to which people could be exposed. This point is difficult if not impossible to find (at the micro-scale level). Nor do we mean the single intersection or street with the maximum number of vehicles per unit time or otherwise atypical characteristics which can not be extrapolated to any other location of the city. We do mean one of a number of similar highly congested street canyons where high values are likely to occur and from which the data can be extrapolated to a limited number of similar areas. Since this is a peak site, an effort should be made to determine the predominately leeward side of the street relative to the general wind flow during maximum traffic conditions (usually during the morning or evening rush hour) and monitor on that side. Figure 1 shows a schematic of cross-street circulation in a street canyon and identifies the leeward side.

2. Average*

This type of site is second in priority and should typify the exposure to which the average commuter, pedestrian, shopper in the CBD may be subjected. The site should typify those areas of average traffic count, congestion and building height. At an average street canyon site, no special pains are necessary to determine the predominately leeward side of the street during maximum traffic flow, but merely let convenience dictate on which side of the street to monitor.

B. Neighborhood

This type of site is representative of those areas of uniform land use (residential and commercial, etc.) away from street canyon effects, in which a captive population i.e., the worker, resident, or invalid is exposed. This is a longer term exposure compared to the commuter and shopper in the street canyon. This type of site is also divided into two types, peak and average.

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*This term 'average' is not meant to suggest that data from different stations be averaged together or combined. Data from each station should be treated separately.

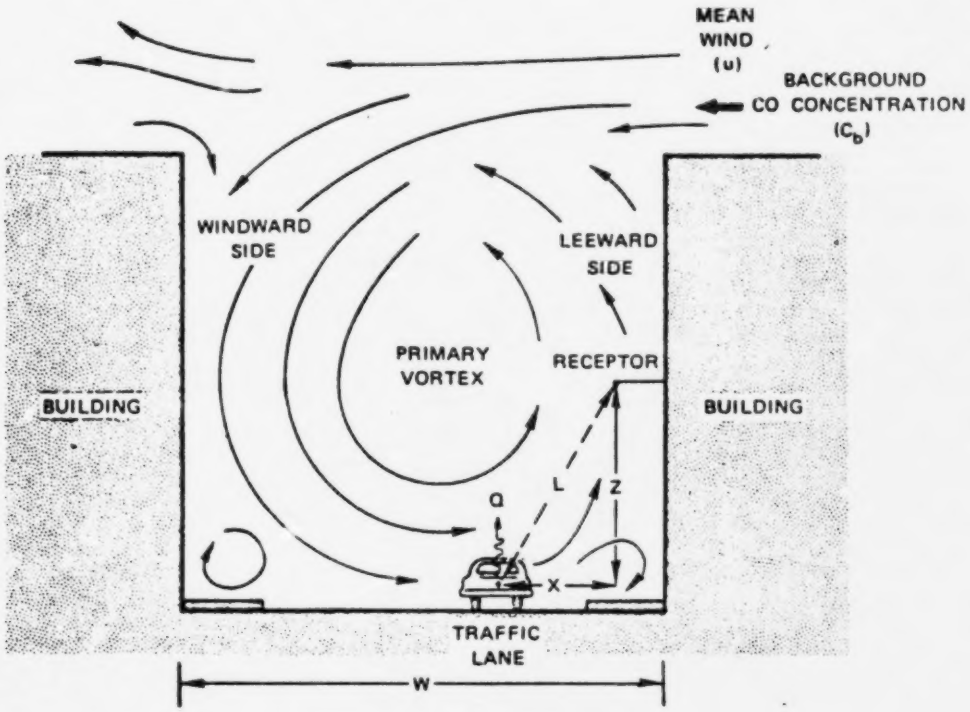

Figure 1-6. Schematic of cross-street circulation in street canyon

1. Peak

This type of site shares top priority with the peak street canyon classification. It is the area away from localized street canyon and major traffic arterial (≈ 50,000 vehicle per day (VPD)) effects. It is where the concentrations to which a large portion of the population may be exposed, are expected to be the greatest.

2. Average

This site is similar to the peak neighborhood site except the expected concentrations would be lower and more representative of those that the majority of the population of a region would be exposed. Data from this type of site could be extrapolated to other neighborhoods of similar characteristics. This type of site is of fifth or lowest priority.

C. Corridor

This type of site is intended to bridge the gap between the street canyon site and the neighborhood site. It is of third priority and intended to describe those areas in which a heavily traveled arterial, (either stop and go or limited access) impinges upon a neighborhood. This arterial should be greater than 50,000 VPD or the most heavily traveled one in the AQCR if none is over 50,000 VPD.

D. Background

Here, we are talking about regional or rural background. This type of site is important as it provides a noncontrollable or natural base line value used in the development of control strategies for attainment and maintenance of ambient air standards. This type of site is listed as priority #4.

IV. SPECIFIC SITE CRITERIA

The site criteria contain specific recommendations concerning such things as spacing between monitors and sources or the heights of inlets and are summarized in tabular format in the summary section. The recommendations have been derived through a variety of methods. In most cases, a

priori judgment is required during some phase of the process. The objective of this section is to make these a priori judgments as recognizable and consistent as possible. This section presents the reasoning and judgments that were used to arrive at the recommendations.

In some cases, such as the recommended heights of inlets, the choices are straightforward. The importance of population exposure to CO concentrations demands that the air be sampled at average breathing heights. However, practical factors, like prevention of vandalism and the potential obstruction to pedestrians, require that the air samples be higher--hence, the recommended 3 m which is an admitted compromise between these two requirements. The recommendation of a range of heights ($\pm$ ½ m) about 3 m is also a compromise between the spatial variability of CO concentration with height and the practical considerations involved in physically locating a monitor.

Similarily, the recommended spacing, or setback distance, between sites and specific sources is clearly understandable if it is restated in terms of the expected maximum contributions of the source to the measured CO concentrations at the site. Thus, we have decided on acceptable levels of the interference by a specific source (for the purpose of this guideline, 1 ppm was selected) and proceeded to find the minimum spacing between the source and the monitoring site where that level is not likely to be exceeded.

Some of the procedures require other kinds of justification. For instance, potential street canyon sites are identified on the basis of traffic on the streets in the area. The recommended procedure uses traffic volumes as a surrogate for CO emissions and CO concentrations. The reasons for this and other recommendations are discussed further in the Stanford Research Institute report on CO monitoring.[3]

By spelling out the reasoning and the assumptions behind the choices that have been made, it should help others to make rational decisions in cases where the requirements of their situation are not covered by the recommendations of this guideline.

A. Street Canyon

It is recommended that inlets for street canyon sampling should be near mid-sidewalk, at least 2 meters from the side of a building and at a height between 2.5 and 3.5 m. The choice of 3 m for the median height has already been explained as compromise between average breathing height and prevention of vandalism.

The recommended 1 m range of heights is also a compromise to some extent. For purposes of consistency and comparability, it would be desirable to have all inlets at exactly the same height, but practical considerations will often prevent this. Therefore, some reasonable range has to be specified and 1 m should be adequate leeway to meet most requirements.

The variability of CO concentration with height in a street canyon is sufficiently large that the representativeness of the measurements will be strongly affected by variability of the inlet height. Georgii et.al (1967)[4] shows vertical gradients of CO concentration from about 0.3 ppm/m to 0.5 ppm/m in the lower levels of a street canyon. Similar gradients were found by Ludwig and Dabberdt (1972).[5] The gradients will depend on traffic emissions and on street canyon dimensions, but available observations and the empirical model presented in Appendix A of the SRI report[3] suggests that hour-average vertical gradients of 1 ppm/m are quite possible. A 1 m range of inlet height then corresponds to a range in concentrations of about 1 ppm or less. This seems a reasonable value for measurements in this kind of environment. The reasonableness of the 1 ppm range can be subjectively judged by comparing it to air quality standards--it is about

2 or 3 percent of the one-hour standard and about 10 percent of the eight-hour standard.

It is recommended that street canyon sensor inlets be located near mid-block, at least 10 m from the intersection. The choice of mid-block locations over intersection locations was made because intersections represent a much smaller portion of downtown space than do the street between them. The pedestrian exposure times are probably also greater in street canyons than at intersections. Finally, the practical difficulties of positioning inlets are less at mid-block locations than at an intersection.

B. Neighborhood

The inlet heights for neighborhood monitoring stations are specified to be between 2.5 and 3.5 m. The rationale is to obtain measurements that are consistent with street canyon type measurements and are taken as near as practical to average breathing heights. As in the case with street canyon monitors, we would like to minimize the differences from the 3 meter elevation. If, however, the 3 + ½ meter inlet height criteria is physically impractical, more flexibility maybe allowed since the expected gradient with height is less (5%/m) than in the street canyon situation (.5 ppm/m). However, actual measured vertical gradients at the specific location should be determined so that the effect of deviation from the standardized criteria could be documented and taken into account.

The presumption has been, in determining minimum separation between a monitoring site and a specific source, that the neighborhood or regional measurements should not be unduly influenced by any single source. A subjective judgment is required as to what constitutes undue influence. There are at least two bases for making that judgment. A maximum concentration value can be assigned and the separation between the monitoring site and all sources should be such that the contribution from any one source does not exceed the assigned maximum. The other approach is to examine the disturbance in the concentration gradients caused by sources and assign a maximum allowable gradient from any given source. Both approaches were tried and are fully documented in

the SRI report on CO siting.[3] Table 1 gives suggested minimum separations to limit the influence from specific roads to approximately 1 ppm:

TABLE 2

Minimum Separation of CO Monitors and Roadways for Neighborhood and Background Sites

Separation Distance	Road Volume	
	Vehicles Per Day	Vehicles Per Max. Hour
3.5 km	100,000	10,000
1.5 km	50,000	5,000
200 m	10,000	1,000
100 m	5,000	500
35 m	1,000	100

Limited bag sampling program could be undertaken to define gradients (especially horizontal) in the area. If the gradients are wide spread, then a location more distant from the nearest street might be required. Conversely, close gradients would allow closer placement at an inlet height of 2.5 to 3.5 m. The vertical gradient for these sites would be approximately 5%/meter.

C. Corridor

A height of 3 $\pm$ ½ meters is recommended for reasons described previously. The distance from the roadway would be a function of where the closest residences or firms were located and the type of roadway involved, i.e., elevated, grade level or depressed. The site would be chosen such that the effect of the corridor would be at least 50% of the reading and the vertical gradient would be less than .3 ppm/m but greater than 5%/m under stability conditions leading to peak levels.

D. Background

A height of 3 to 10 meters is recommended, the vertical gradient should be approximately 5% in this range, the same as for the 1 meter range in the city. To limit the effect of line sources to .2 ppm, which is considered global carbon monoxide background,[8] the site should be 5 to 6 km away from any interurban

highway carrying 3000 cars/peak hour and 400 m away from any road carrying over 100 cars/day. The background site should also be 35 km downwind in the least frequent wind direction from the urban area. This will also limit the effect of the urban area to $\approx$ .2 ppm.

E. Review Of New Sources

1. Pre-Construction

The role of the ambient CO monitoring station in new source review is to provide a means for estimating high urban background values likely to persist for 1- or 8-hour periods at the site of a proposed source. These data are usually collected for a short time span and are then adjusted to account for seasonal variations observed at more permanent sites. Estimates obtained using an appropriate modeling procedure[1] are superimposed over the seasonally adjusted peak 1- and 8-hour CO values obtained through monitoring. Again, the seasonally adjusted monitoring values serve to estimate urban background concentrations at the site of a proposed source which are independent of the source.

In order to adequately fulfill the role of monitored data in the pre-construction new source review, a monitoring station could be most closely categorized as a neighborhood site. There are several specific siting criteria which should be observed: The probe should be 3 $\pm$ ½ meters high. Such placement is about as close as one can come to breathing height and still offer reasonable security for the instrument against the casual passersby or vandals. In addition, this probe height is consistent with the height recommended for other types of stations and so a more ready comparison with data collected elsewhere is possible. The $\pm$ ½ meter tolerance is to accommodate features of an otherwise suitable site which may make it impossible to place the probe at exactly 3 meters above ground. The probe should be located at least 100 meters from any existing street or road. The monitoring data used in pre-construction review

are used to estimate urban background concentrations which are independent of the source and traffic on the roads adjacent to the source. Unless a monitors position is carefully documented, placement of a probe within 100 meters of a road could result in counting the effects of road traffic twice in the review procedure. In the event that it is not possible to find a suitable monitoring site which is at least 100 meters drom any existing road, the exact distance of the probe from the newest roads should be measured and recorded. This procedure is necessary in order to adapt the modeling procedure[1] to avoid counting the effects of traffic on the existing roads more than once.

2. Post-Construction

The EPA regulations for new source review do not require monitoring of ambient CO after the initial pre-construction review has been satisfactorily completed. It may sometimes be of interest to monitor near arterial streets or roads servicing an existing source in order to establish whether the NAAQS are being attained or maintained or to help in determining air quality trends. Sites used for these purposes will be expected to operate for longer periods than the preconstruction sites. In most cases, these sites could be categorized as corridor sites (or street canyon sites if a central business district is affected). Specific siting criteria aimed at fulfilling these objectives using data from such site categories should be observed in placing the site.

V. DATA REPORTING, SUMMARIZATION AND USE

A. Site Not Meeting Criteria

CO monitoring sites whose probe locations do not conform to the recommended criteria, are not necessarily producing invalid or unuseful data. In many cases, the specific monitoring objective for which the site was chosen to satisfy may be adequately met. The SRI report[3] gives formulas and computer programs to determine what the bias or effect of deviating from the criteria will be. This should be calculated and minor

deviations may be factored into the air quality analysis. It may be that the arbitrarily chosen limiting influence associated with the criteria of this guideline are too restrictive or too lax for a given region's monitoring objective. Again, this should pose no problem if the rationale behind the probe criteria is understood and the effects of deviations from the criteria are taken into account.

B. Use Of Data

It should be emphasized that all properly located sites should be used in the evaluation of control strategies and/or for determining compliance with primary standards, both 1- and 8-hour. For strategy purposes, however, the scale of control action should be consistent with the scale of the ambient problem which is a direct function of the scale of representativeness of each particular site. A violation of the NAAQS at a single monitoring station may signal the need for a range of possible actions varying in intensity from city-wide control measures, on one hand, to a small scale action plan designed to alleviate traffic conjestion at specific intersections. (For example, if the data from an average neighborhood site were above the 8-hour standard, this could imply a totally different control plan than if similar values were measured at only a peak street canyon site). Again, the specific control action required should be tailored to fit the scale of ambient problem and the degree to which particular monitors typify exposures over a large area of the region being monitored.

VI. SUMMARY

This guideline consolidates, updates, and extends the information contained in several previous documents[7-11] and should therefore supersede all previous information with regards to CO monitoring. Much of this information was taken from the Stanford Research Institute report[3] on selecting sites for CO monitoring. This latter report should be consulted for further discussion and procedures to follow in obtaining background information, and selecting general monitoring areas. The report[3] also describes the rationale behind

the development of the specific probe exposure criteria and the effects of deviation from the criteria. Table 2 summarizes specific probe exposure criteria for the various site types.

In conclusion, it is apparent that one set of criteria to be applied to all CO sites is inappropriate and technically unsound. The criteria presented have been tailored to the monitoring objective. The data must be evaluated in terms of the objective, whether it meets the criteria, or how far it deviates from the criteria. The scale of control action must take all these factors into consideration.

TABLE 3. SPECIFIC PROBE EXPOSURE CRITERIA

Site Type	Height Above Ground	Expected Concentration Gradient with Height (1-hr. Average)	Separation of Monitor from influencing Sources	General Remarks
Street Canyon				Central Business District High density slow moving traffic. Dense multiple story buildings lining both sides of street. > 10 m from intersection.
Peak Conc.	3 ± ½ m	≈ .5 ppm/m	mid sidewalk or 2 m from side of building. On leeward side of street.	
Average Conc.	3 ± ½ m	≈ .3 ppm/m	mid-sidewalk or 2 m from side of building.	
Neighborhood			Setback / VPD: 3.5 km / 100,000; 1.5 km / 50,000; 200 m / 10,000; 100 m / 5,000; 35 m / 1,000; 25 m / any	Commercial or residential neighborhood. This separation criteria limits the effect of these streets to ≈ 1 ppm.
Peak Conc.	3 ± ½ m	5%/m		
Average Conc.	3 ± ½ m	5%/m		
Corridor	3 ± ½ m	< .3 ppm/m > 5%/m	Dependent on traffic volume, road configuration and setback distance of commercial or residential activity.	Stop and go or limited access traffic > 50,000 VPD or greatest in area.

TABLE 3. SPECIFIC PROBE EXPOSURE CRITERIA (CONTINUED)

Site Type	Height Above Ground	Expected Concentration Gradient with Height (1-hr. Average)	Separation of Monitor from influencing Sources	General Remarks
Background	3 to 10 m	.2%/m	5 to 6 km; > 3000 VPH max 400 m; > 100 VPD	35 km downwind in least frequent wind direction from city, limit effects to .2 ppm.
New Source Review				
Preconstruction	3 ± ½ m	5%/m	usually the same as neighborhood	Area of lowest concentration in proposed indirect source location for background.
Post-Construction	3 ± ½ m	> 5%/m to < .5 ppm	usually the same as corridor or street canyon	Area of maximum concentration in area of complete area source.

VII. REFERENCES

1. U.S. EPA, Office of Air and Waste Management, Office of Air Quality Planning and Standards; "Guidelines for Air Quality Maintenance Planning and Analysis, Volume 9: Evaluating Indirect Sources;" EPA-450/4-75-001 (January 1975); Air Pollution Technical Information Center, RTP, N.C. 27711.

2. (41 CFR 51.17) Federal Register Vol. 36., No. 228, pp. 22384-22403.

3. "Selecting Sites for Carbon Monoxide Monitoring" F. L. Ludwig and J. H. S. Kealoha. Stanford Research Institute project 35-15, prepared for the Environmental Protection Agency, under contract #68-02-1471, July 1975.

4. Georgii, H.W., E. Busch, and E. Weber, 1967: "Investigation of the Temporal and Spatial Distribution of the Immission Concentration of Carbon Monoxide in Frankfurt/Main," Report No. 11 of the Institute for Meteorology and Geophysics of the University of Frankfurt/Main (Translation No. 0477, NAPCA).

5. Ludwig, F.L. and W.F. Dabberdt, 1972: "Evaluation of the APRAC-1A Urban Diffusion Model for Carbon Monoxide," Final Report, Coordinating Research Council, EPAC Contract CAPA-3-68 (1-69), Stanford Research Institute, Menlo Park, California, 147 pp.

6. Robinson, E. and R. C. Robbins, 1967: "Sources, Abundance, and Fate of Gaseous Pollutants," prepared for Amer. Petroleum Inst. Final Report, Project PR-6755, Stanford Research Institute, Menlo Park, Calif.

7. Guidelines: Air Quality Surveillance Networks, Environmental Protection Agency, AP-98, May 1971.

8. Guidelines for Technical Services of a State Air Pollution Control Agency - Appendix A, Environmental Protection Agency, APTD-1347, November 1972.

9. OAQPS Guideline Series 1.2-007, Air Quality Monitoring Interim Guidance, August 1973.

10. OAQPS Guideline Series 1.2-012, Guidance for Air Quality Monitoring Network Design and Instrument Siting Draft Version, January 1974.

11. OAQPS Guideline Series #1.2-019, Air Quality Monitoring Site Description Guideline, (Draft) 1974.

APPENDIX B

The following are several possible methods for determining a more adequate number of stations for an AQCR as contrasted to the minimum required based on varying levels of information. Note that the actual number of stations finally decided upon for a Region should be the result of tempering the derived number by practical considerations, resources available, fuel use patterns, and source configurations. Also the total adequate number of monitors is found by summing the number necessary for the urban area together with those needed for isolated point sources discussed in Section 3.5.

a. Method A Isopleth Maps (SO_2 and TSP Only)

An adequate number of stations can be approximated from information on existing levels of pollution as a function of the area of the region. Isopleth maps resulting from diffusion models (See Appendix D) are useful in this determination. At the present time, use of this mathematical approach is limited to the design of the monitoring networks for suspended particulates and sulfur dioxide.

The equation for estimating adequate network size relates the number of stations to the degree of pollution and the land area of the region. It is based on the fact that more stations are needed in zones where ambient air pollutant concentrations may be expected to exceed the ambient air quality standards. The equation considers distinct areas: the area, X, where the pollution levels are higher than the ambient air quality standard; the area, Y, where pollution

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levels are above background but lower than the standard; and the area, Z, where existing concentrations are at background levels. In these equations all air quality data are expressed in terms of annual averages. The total number of samplers, N, required for the entire region is obtained by summing the estimated numbers of samplers for each of the three subareas:

$$N = N_x + N_y + N_x$$

The subareas are described as follows:

$$N_x = 0.0965 \quad \frac{C_m - C_s}{C_S} X$$

$$N_y = 0.0096 \quad \frac{C_s - C_b}{C_s} Y$$

$$N_z = 0.0004 Z$$

Where:

C_m = Value of maximum isopleth (with a contour interval of 10), $\mu g/m^3$

C_s = Ambient air quality standard, $\mu g/m^3$ annual average

C_b = Value of the minimum isopleth (with a contour interval of 10), $\mu g/m^3$ annual average

X = Area wherein concentrations are higher than ambient air quality standard, km^2

Y = Area wherein concentrations are above background but less than ambient standard, km^2

Z = Area wherein concentrations are at background levels, km^2

Estimated background values for total suspended particulates and SO_2

TABLE 1

TSP AND SO_2 VALUES FOR NONURBAN BACKGROUND TERM
($\mu g/m^3$)

	Proximate[a]	Intermediate[b]	Remote[c]
Total suspended particulate	45	40	20
Sulfur dioxide	20	10	5

[a]Proximate values based upon NASN stations in the following states: Connecticut, Delaware, District of Columbia, Maryland, Massachusetts, New Jersey, New York, Pennsylvania, Rhode Island

[b]Intermediate values for all other states.

[c]Remote values based upon NASN stations in the following states: Colorado, Idaho, Minnesota, Montana, Nebraska, Nevada, New Hampshire, New Mexico, North Dakota, Utah, Wisconsin, Wyoming.

for use when isopleth information is not available are listed in Table 1.

Use of these equations requires the division of the region into three zones on the basis of iso-intensity lines representing the ambient air quality standard and the background value appropriate for the region. The land areas of each zone are determined from the isopleth map, as are the maximum and minimum concentrations in the region. The above equations should not be used to estimate the numbers of background stations where regions encompass large unpopulated areas. No more than two or three background stations should be necessary in any region.

The equation for determining number of stations was derived from an analysis of the relationship between pollution levels and patterns, geometric distribution of sources, meteorology, and land area in the National Capital Interstate Air Quality Control Region. The equation was applied to several other cities in the United States with various population and pollutant distributions. As mentioned earlier, it is applicable only to SO_2 and TSP networks.

An application of the above to Washington, D.C. data for suspended particulate matter yields the following:

$C_m = 100 \ g/m^3$

$C_s = 75 \ g/m^3$

$C_b = 40 \ g/m^3$

$X = 417 \ Km^2$

$Y = 3089 \ Km^2$

$Z = 2231 \ Km^2$

$N_x = 0.0065 \left(\frac{100 - 75}{75}\right) 417$

$= 13$

$N_y = 0.0096 \left(\frac{75 - 40}{75}\right) 3889$

$= 17$

$N_z = .0004\ (2231)$

$= 1$

$N = N_x + N_y + N_z$

$= 13 + 17 + 1$

$= 31$

b. Method B Multiplication Factors (SO_2, TSP, Oxidants, NO_2)

If past air quality and/or model information are not available, then the adequate number of monitoring stations for particulates, sulfur dioxide, nitrogen dioxide, and oxidants can be determined by adjusting the minimum number through a multiplication process with factors which influence air quality levels discussed in Section 3.1. The procedure is outlined below:

$N_p = (T_F \times C_F) \times M_p$

where N_p = adequate number of stations required for a given pollutant

T_F = Topography Factor

C_F = Climatology Factor

M_p = Minimum number of monitoring stations for a particular pollutant (from Table 1 Section 3.2)

TOPOGRAPHY FACTOR

Regime	Description	Factor
Valley-ridge	Continuous contours of greater than 300 feet between a valley and a ridge within a mile of the horizontal distance	1.8
Hilly-mountainous	Terrain elevations greater than 800-1000 feet between hills or mountains and valley floor	1.5
Shoreline	Bodies of water of a size at least equal to the Great Salt Lake	1.2
Level or gently rolling	No marked contours or shorelines	1.0

These topographic factors are relative numbers based on the factors influencing air quality discussed in the previous section for each of the regimes listed. The description used should describe the urban area of the AQCR or where the worst pollution areas are located rather than the entire sampling area to be covered. It may be necessary to subdivide the AQCR if the topographic features are significantly variable.

CLIMATOLOGY FACTOR

Atmospheric Area[a]	Short-Term[b]	Long-Term[c]
California-Oregon coastal	2.0	1.6
Washington coastal	1.4	1.4
Rocky Mountain	2.0	1.1
Great Plains	1.0	1.0
Great Lakes-Northeast	1.1	1.4
Appalachian	1.6	1.4
Mid-Atlantic coastal	1.4	1.0
South Florida	1.0	1.0
Tropical	1.0	1.0
South Coastal Alaska	1.5	1.5
North and Central Alaska	2.0	1.8

Note: The use of the short and long-term factors should be according to the particular pollutant for which the network is being designed.

Pollutant	Factor
Nitrogen dioxide	Long-term
Sulfur dioxide	Short-term; long-term
Suspended particulates	Short-term; long-term
Oxidants	Short-term

For sulfur dioxide and particulates, the choice of factor should be based on which one is quantitatively greater in the particular Atmospheric Area being considered.

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[a] See Appendix A

[b] Based on isopleths of total number of forecast-days of high meteorological potential for air pollution in a 5-year period. (Holzworth, AP-101, 1972 (Fig. 71))

[c] Based on a consideration of ranking average ventilation factors (Holzworth, AP-101, 1972 (Table 3))

As an example, the determination of an adequate number of sulfur dioxide samplers for a Region with the following characteristics is as follows:

Population = 7,800,000

Topography = shoreline

Atmospheric Area = Mid-Atlantic coastal

T_F (shoreline) = 1.2

C_F (Mid-Atlantic coastal) = 1.4 (short-term is higher)

M_p (sulfur dioxide) = 6 + 0.05 per 100,000 population

= 6 + 0.05 (78)

= 10

$N_{\text{sulfur dioxide}}$ = (1.2 x 1.4) x 10

= 17

APPENDIX C

SCREENING PROCEDURE* FOR DETERMINING THE NECESSITY OF MONITORING ELEVATED POINT SOURCES

The screening procedure in a step-by-step manner is as follows: Steps 1 through 4 are used to determine plume rise for various wind speeds. If there is more than 1 stack, each stack should be considered separately through Step 8. Step 5 determines the effective height of emission for the various wind speeds. Steps 6 through 8 determine the maximum 1-hour concentration from the source and Step 9 estimates the concentration for a slightly longer averaging time. Step 10 estimates the total maximum concentration by adding the background to that due to the point source. Step 11 compares the estimated maximum concentration with the standard and the result indicates whether or not the source exceeds the standard. The required source information is:

Q = maximum emission rate at peak production of the plant for the pollutant considered, g sec^{-1}

h = physical stack height above the ground, m

d = inside top diameter of the stack, m.

v_s = stack gas exit velocity, m sec^{-1}

T_s = stack gas exit temperature, °K

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* Abstracted from "A Sample Screening Technique for Estimating the Impact of a Point Source of Air Pollution Relative to the Air Quality Standards," D.B. Turner and E.L. Martinez, EPA, April 1973. This paper is still in draft form and has not been officially cleared, therefore, this procedure is interim and subject to some later revision.

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Step 1

Find stack gas volume flow from:

$$V_f = 0.785\ v_s d^2$$

Step 2

Find the buoyancy flux parameter from:

$$F = 3.12\ V_f \frac{T_s - 293}{T_s}$$

Step 3

Find the product of plume rise times wind speed by the following:

If F is less than 55:

$$\Delta H.\quad = 21.4\ F^{3/4}$$

where ΔH is plume rise, m

and u is wind speed, m sec^{-1}

If F is greater than or equal to 55:

$$\Delta H.u\ = 38.7\ F^{3/5}$$

Step 4

Determine the plume rise, H, for each of these five wind speeds: 0.5, 1.0, 2.0, 3.0, and 5.0 m sec^{-1}

These are found from:

$$\Delta H\ = (\Delta H.u)/u$$

Step 5

Find the effective height of emission, H, for each of the above wind speeds. H is in meters.

$$H = \Delta H + h$$

Step 6

For each of the 5 H's corresponding to the 5 wind speeds estimate $\chi u/Q$ from Figure 5 as a function of H.

Alternatively, each $\chi u/Q$ can be estimated from the equation:

$$\chi u/Q = a\ H^b$$

where a and b are as given in the following table for the appropriate range of H.

Range of H (meters)	a	b
10 to 20	0.05405	-1.587
20 to 50	0.07537	-1.698
50 to 100	0.03612	-1.510
100 to 2000	0.02164	-1.399

Step 7

For each $\chi u/Q$ found in Step 6, determine the χ/Q corresponding to each wind speed as follows:

$$\chi/Q = \frac{\chi u/Q}{u}$$

If there is more than one stack being considered, Steps 1 through 8 must be applied for each stack separately. The values

found for each stack in Step 8 are then added together. This value of the concentration can be considered a maximum for the 1-hour averaging time.

Step 8

Using the maximum of the five x/Q values found in Step 7, find the concentration, x_{ph}, due to this point source from:

$$x_{ph}(ugm^{-3}) = 10^6 \; Q \; x/Q$$

Step 9

If the above value is to be compared with an air quality standard having a different averaging time, determine the x_p by multiplying xph by the appropriate value in the following table.

Figure 1. Maximum $\chi u/Q$ as a Function of Effective Height of Emission, H, where χ is Concentration, u is Wind Speed, and Q is Emission Rate.

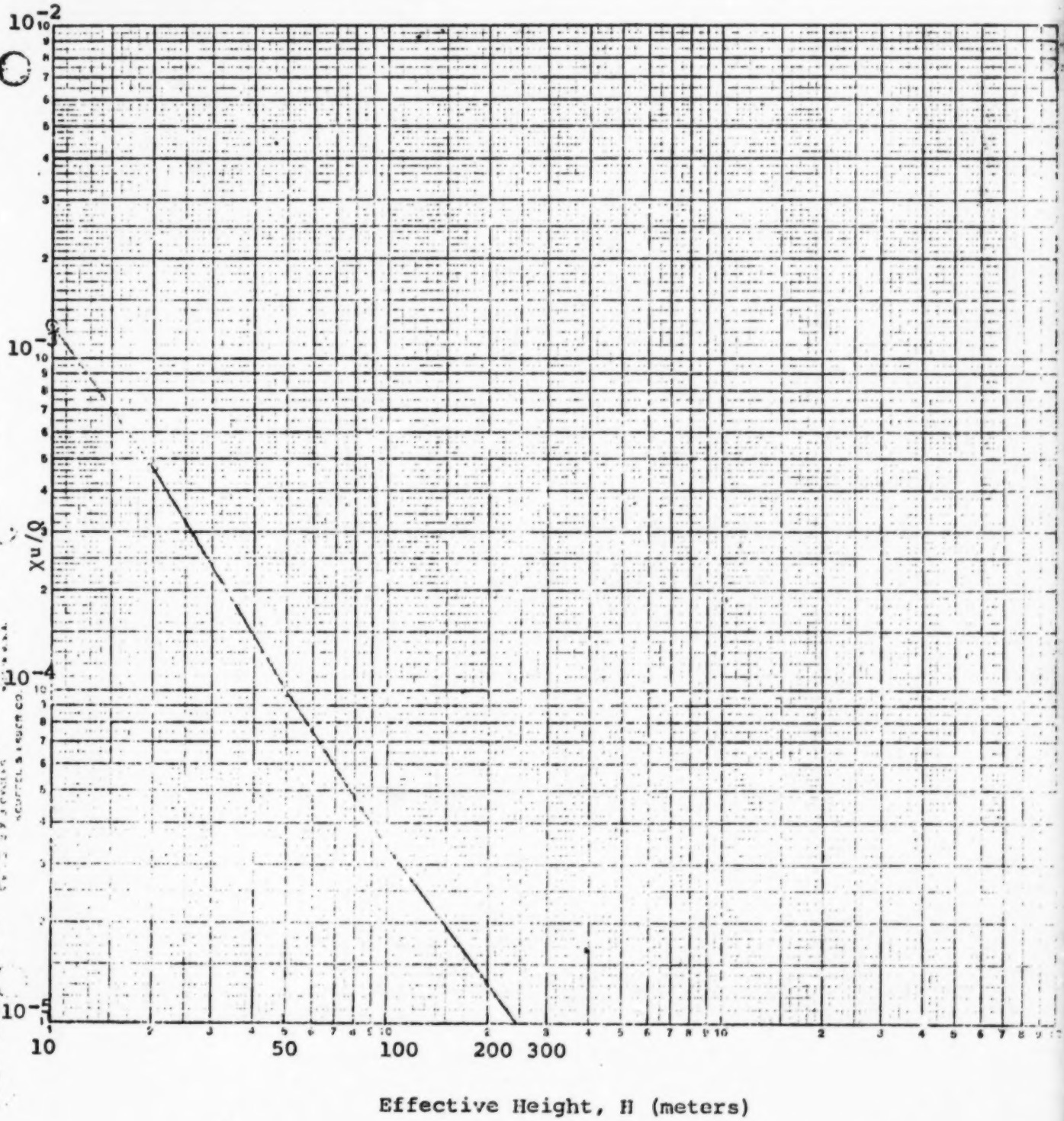
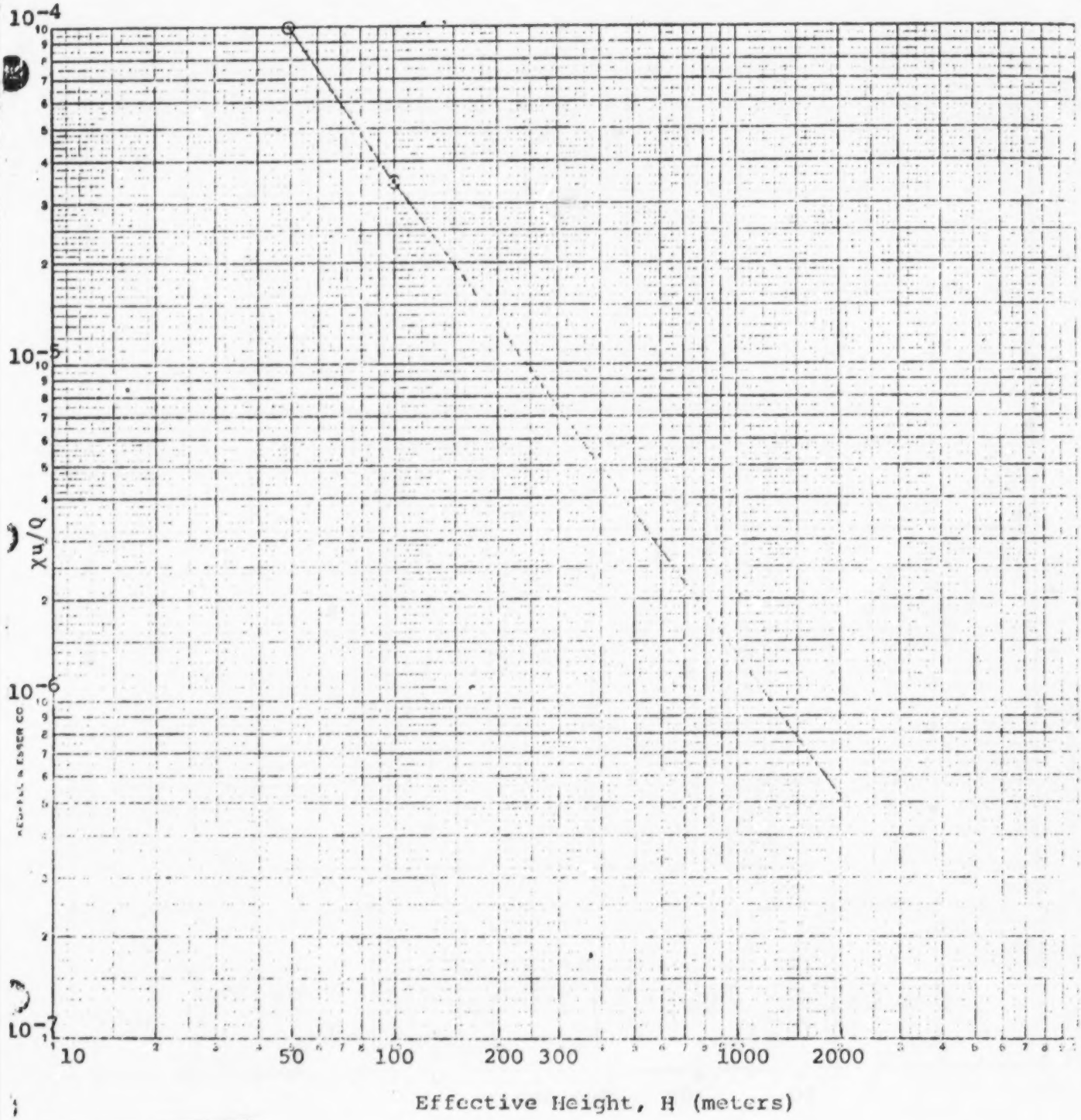


Figure 1, Continued



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Averaging Time	Correction
1 hour	1.0
3 hours	0.75
24 hours	0.25

Step 10

Find the quantity x_{max}, where B is the maximum expected background concentration of the pollutant considered for the averaging time and frequency of occurrence of the standard within a 10 kilometer radius of the source considered, that is, due to other sources than the one being considered, and x_p is the maximum short-term concentration from the point source from Step 9.

$$x_{max} = B + x_p$$

Step 11

S is the short-term air quality standard ($\mu g\ m^{-3}$). If x_{max} is less than 1/2 S, it is probable that the source considered will not cause concentrations exceeding the short-term air quality standard and therefore source monitoring is not required.

If x_{max} is more than 2S, it is almost certain that the source concerned will cause concentrations exceeding the short-term standard and therefore source monitoring should be undertaken.

If x_{max} is more than 1/2S but less than 2S, more detailed analysis of the impact of this source upon air quality should be performed to determine if source monitoring is required.

An example of this procedure is as follows:

A source emits sulfur dioxide at a rate of 1200 grams per second from a stack which is 100 meters high and has an inside diameter of 3 meters. The stack gas velocity is 7.6 meters per second and the stack gas temperature is 420°F (489° Kelvin). Sho Should monitoring be recommended for this plant?

a. Compute the stack gas volume flow from:

$V = 0.785\ V_s d^2 = (0.785)\ (7.6)\ (3)^2 = 53.7\ m^3/sec$

b. Compute the buoyancy flux $F = 3.12\ V\ (1-\frac{T_a}{T_s})$. Assume ambient temperature is 68°F = 293K. $F = (3.12)\ (53.7)\ (1-\frac{293}{489}) = 67.2\ m^4/sec^3$

c. Since F is greater than 55, $\Delta H.u = 38.7\ F^{3/5} = (38.7)(67.2)^{3/5} = 483\ m^2/sec$

d. Determine plume rise for each of five wind speeds:

(1) u = 0.5, $\Delta H = (\Delta H.u)/u = 483/.05 = 966m$

(2) u = 1.0, $\Delta H = 483/1 = 483m$

(3) u = 2.0, $\Delta H = 483/2 = 242m$

(4) u = 3.0, $\Delta H = 483/3 = 161m$

(5) u = 5.0, $\Delta H = 483/5 = 97m$

e. Find the effective height of emission (plume height) $H = \Delta H + h$, for each wind speed

(1) 966 + 100 = 1066

(2) 483 + 100 = 583

(3) 242 + 100 = 342

(4) 161 + 100 = 261

(5) 97 + 100 = 197

f. Estimate $\chi u/Q$ from Figure 4 for each wind speed, and divide by u in each case to get χ/Q:

(1) $(1.25 \cdot 10^{-6})/(0.5) = 2.5 \times 10^{-6}$

(2) $(2.9 \cdot 10^{-6})/(1.0) = 2.9 \times 10^{-6}$

(3) $(6.2 \cdot 10^{-6})/(2.0) = 3.1 \times 10^{-6}$

(4) $(9.5 \cdot 10^{-6})/(3.0) = 3.1 \times 10^{-6}$

(5) $(13.6 \cdot 10^{-6})/(5.0) = 2.7 \times 10^{-6}$

g. The maximum χ/Q in the above step is 3.1×10^{-6}. Using this value, and a Q of 1200 g/sec. $= [\chi/Q](Q) = (3.1 \times 10^{-6})\ (1200)$

$= 3700 \cdot 10^{-6} g/m^3 = 3700\ \mu g/m^3$.

Since this value (3700) is more than 1/2S (or 1300) but less than 2S (or 5200), a more detailed analysis of the impact of this source should be performed for air monitoring purposes.

APPENDIX D

COMPUTERIZED ATMOSPHERIC DIFFUSION MODELS AVAILABLE FROM EPA

Numerous variations of atmospheric diffusion models exist which may be utilized in the design of air quality monitoring networks. The Air Quality Display Model (AQDM) is suitable for the long-term, urban applications involving sulfur oxides and particulate matter. Other models are available including those in the EPA UNAMAP system designed for interactive remote computer terminal operation and are readily available to EPA Regional Offices. The latest UNAMAP catalog of models, with a brief description of each, is presented below. A comprehensive air quality modeling guideline is presently being developed by the Monitoring and Data Analysis Division.

There are no models which adequately describe the source-receptor relationship for photochemical air pollutants. A few models of this type are under development and some may be available in the near future.